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OPTICAL TUNABLE MICROWAVE FILTER USING HIGHER MODE

Abstract:

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(71) Applicant *(for all designated States except US)*: **YONSEI UNIVERSITY** [KR/KR]; Yonsei University, 134, Sinchon-Dong, Seodaemun-Gu, Seoul 120-749 (KR).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CHOI, Woo-Young** [KR/KR]; 2-701 Kwangnam Caesbil, 512-5 Changchun-Dong, Seodaemun-Gu, Seoul 120-836 (KR). **LEE, Kwang-Hyun** [KR/KR]; 962-16 (4/5) Bangbac2-Dong, Seocho-Gu, Seoul 137-846 (KR).

(74) Agent: **PARK, Sungmin**; 3F. Dongbo Bldg., 647-8 Yoksam-Dong, Gangnam-Gu, Seoul 135-080 (KR).

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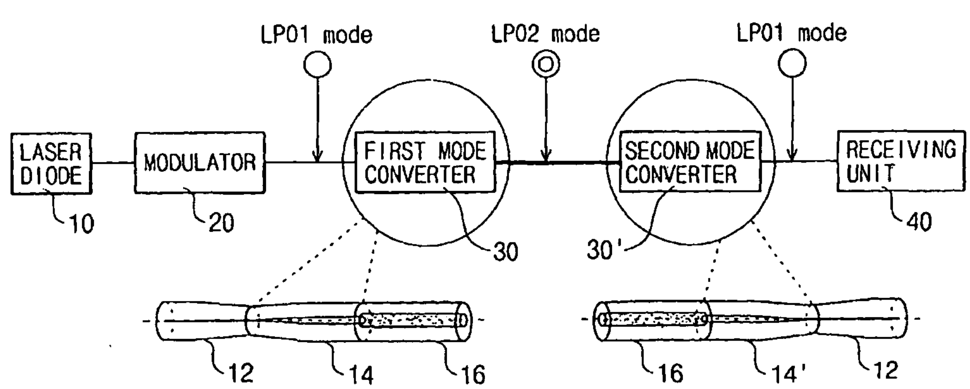

(57) Abstract: Disclosed is an optical tunable microwave filter using higher mode. The filter comprises a laser diode producing carrier signals; a modulator modulating the signals produced by the laser diode; a first mode converter being input power of the modulated signals by the modulator and dispersing the power of the input signals, namely the power of the signal with a mode (LP01) in a single mode fiber, into two modes (LP01, LP02) in a dispersion compensation fiber; a second mode converter being input two modes (LP01, LP02) signals having time delay through the first mode converter and converting the input modes (LP01, LP02) signals into a mode (LP01) existing in the single mode fiber; a receiver receiving the signals converted by the second mode converter.

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OPTICAL TUNABLE MICROWAVE FILTER USING HIGHER MODE

Technical Field

The present invention relates, in general, to a optical tunable microwave filter using a higher mode and, more particularly, to a filter that can construct a plurality of delay lines using a single short dispersion compensation fiber through two mode converters.

Background Art

Generally, components required to manufacture a filter are delay lines for changing the phase of a signal. In order to construct these delay lines, most filters, which have been proposed until now, use high-dispersion fibers 5 as shown in Fig. 1. That is, a signal output from a laser diode 1 is modulated and amplified in order by an RF modulator 2 and an amplifier 3, respectively, and the modulated signal is divided into several signals by a divider 4 (in the ratio of 1:8 in Fig. 1). Further, several paths 8 for allowing these signals to pass therethrough are formed, and the high-dispersion fibers 5 having different lengths are connected to respective paths 8, thus constructing a plurality of delay lines. In this way, signals passing through respective delay lines are detected by photodiodes which are detectors 6, and characteristics of the filter can be obtained using detected frequency characteristics. Further, the signals detected by the detectors 6 are output through a 8:1 RF power combiner 7.

However, in the conventional filter having the above construction, one high-dispersion fiber constructs one delay line. Further, since a detector is necessary for each path, as many detectors as the number of required delay lines are necessary. Further, in order to construct required delay lines, high-dispersion fibers each with a length greater than several tens of meters are required, which acts as an unfavorable factor in the size and cost of a filter.

Therefore, a method of constructing a plurality of delay lines using a

single short fiber and a single detector is required.

Disclosure of the Invention

Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an object of the present invention is to provide a optical tunable microwave filter using a higher mode that can construct a plurality of delay lines using a single short dispersion compensation fiber and a single detector through two mode converters.

Terms used in the description of the present invention are defined in brief below.

Higher mode: modes except for a main mode with a lowest cutoff frequency

Dispersion Compensation Fiber (DCF): one of wavelength division multiplexing transmission methods attempted to transmit a signal at a speed higher than 10 Gbps, wherein a DCF having a dispersion value opposite to a typical optical fiber is arranged in the middle of a transmission path, thus compensating for dispersion

Single Mode Fiber: optical fiber having a single propagation mode in which used wavelengths can be transmitted, the optical fiber being characterized in that the diameter of a core thereof is very small to be less than 10 μm and a single light propagation mode exists, so signal loss is small and there is no signal transformation (distortion), thus enabling signals to be transmitted over a long distance.

Hollow Optical Fiber: optical fiber having a hollow center portion

Group Velocity: velocity at which a signal wave is propagated, and the reciprocal of the rate of change of the phase constant with respect to angular frequency in a specific mode

Group Index: for a given mode propagating in a medium of refractive index n, index value obtained by dividing the velocity of light in a vacuum by the group velocity of the mode

Delay line: means for introducing a time delay

Brief Description of Drawings

Fig. 1 is a view showing the construction of a conventional filter;

Fig. 2 is a view showing the construction of a filter according to the present invention; and

Fig. 3 is a view showing the construction according to another embodiment according to the present invention.

Best Mode for Carrying Out the Invention

Hereinafter, embodiments of the present invention will be described in detail with reference to the attached drawings.

<embodiment>

Construction

The entire construction of a filter of the present invention is described with reference to Fig. 2.

The present invention provides a filter comprised of first and second mode converters 30 and 30', a single mode fiber 12, a dispersion compensation fiber 16, a laser diode 10, a modulator 20, and a receiving unit 40.

The filter of the present invention comprises the laser diode 10 for generating a carrier signal; the modulator 20 for modulating the carrier signal generated by the laser diode 10; the first mode converter 30 for receiving power of the signal modulated by the modulator 20 and dispersing the signal power, that is, the power of the signal transmitted in a single mode LP01 in the single mode fiber 12, into two modes LP01 and LP02 in the dispersion compensation fiber 16; the second mode converter 30' for receiving signals of two modes LP01 and LP02 having a time delay therebetween through the first mode converter 30 and converting the signals of the two modes LP01 and LP02 into a signal of a single mode LP01 in the single mode fiber 12; and the receiving unit 40 for receiving

the signal converted by the second mode converter 30'.

In this case, the first and second mode converters 30 and 30' are hollow optical fibers 14 and 14' that each couple the single mode fiber 12 and the dispersion compensation fiber 16 and each have a radius of 3.4μm and an empty space with a radius of 0.6μm in its center.

The modes LP01 and LP02 of the present invention are described below.

Generally, a Transverse Electric (TE) mode, a Transverse Magnetic (TM) mode and a Hybrid mode exist in an optical fiber. In this case, the TE mode is a mode in which a H-field (magnetic field component) exists, not an E-field (electric field component), in the direction of propagation of electromagnetic waves. The TM mode is a mode in which an E-field (electric field component) exists, not a H-field (magnetic field component), in the direction of propagation of electromagnetic waves. Further, the hybrid mode is a mode in which an E-field and a H-field exist in the direction of propagation of electromagnetic waves, differently from the TE and TM modes. Refractive indexes of the modes can be obtained through characteristic equations, which are obtained by applying boundary conditions to a wave equation and are different from each other according to the TM, TE and Hybrid modes.

Meanwhile, if refractive indexes of a core and a cladding of an optical fiber are almost the same, there are modes in which the refractive indexes of the above modes become almost equal at the time the refractive indexes thereof are obtained. These modes are integrally called a Linearly polarized (LP) mode. Further, in LPmn of the LP mode, m is an index included in the characteristic equations obtained by applying the boundary conditions to the wave equation, and n is the sequence of solutions obtained by applying a given index m to the characteristic equations. That is, LP01 is a mode having a refractive index corresponding to a first value of solutions obtained by applying m =0 to the characteristic equation of LPmn, and LP01 is a mode having a refractive index corresponding to a second value of solutions obtained by applying m =0 to the characteristic equation of LPmn.

Operation

An operating principle of the construction of the present invention as described above is described with reference to Fig. 2.

First, if the laser diode 10 generates a carrier signal, the generated carrier signal is intensity-modulated by the modulator 20. In this case, the power of the modulated signal is transmitted in only a single mode existing in the single mode fiber 12, that is, the LP01 mode, and the transmitted signal power is input to the first mode converter 30.

The first mode converter 30 is formed in such a way that the single mode fiber 12 and the dispersion compensation fiber 16 are coupled through the hollow optical fiber 14, and the function of the first mode converter 30 is described below.

The first mode converter 30 serves to disperse the power of the signal transmitted only in the LP01 mode. As the power of the modulated signal, transmitted only in the LP01 mode within the single mode fiber 12, passes through the first mode converter 30, the shape of a mode changes to a ring shape. This ring-shaped LP01 mode is dispersed into two modes existing in the dispersion compensation fiber 16, that is, modes LP01 and LP02, in the power ratio of 50:50. As described above, the first mode converter 30 serves to allow the signal being propagated in the single mode LP01 to be dispersed into two modes LP01 and LP02 and propagated. Further, as described above, the mode is changed to be ring-shaped while the signal power passes through the hollow optical fiber 14. The reason for this is to more effectively perform mode coupling to the LP02 mode existing in the dispersion compensation fiber 16.

Signals transmitted in the two modes LP01 and LP02 dispersed in this way pass through the dispersion compensation fiber 16 with different group indexes and group velocities in the dispersion compensation fiber 16, which represents that a time delay occurs due to a velocity difference between two modes even though the signals are propagated in two modes LP01 and LP02 by

the same length. In this way, the signals of two modes LP01 and LP02 having a time delay therebetween pass through the second mode converter 30'. The second mode converter 30' converts the signals of two modes LP01 and LP02 again into a signal of the single mode LP01 existing in the single mode fiber 12. The signal, converted into the signal of the LP01 mode existing in the single mode fiber 12 through the second mode converter 30', is received by the receiving unit 40. In this case, the second mode converter 30' is the hollow optical fiber 14' for coupling the single mode fiber 12 and the dispersion compensation fiber 16, similar to the first mode converter 30.

Through the above operation, the characteristics of the filter can be obtained by measuring frequency response characteristics while increasing a modulation frequency of the signal received by the receiving unit 40.

Meanwhile, a tuning method of the filter proposed in the present invention is described below.

If a laser wavelength of the laser diode 10 is varied, group velocities of respective modes LP01 and LP02 have values differing from those measured before the wavelength of the laser is varied, due to mode characteristics in the dispersion compensation fiber 16. These different group velocities vary a time delay between the two modes LP01 and LP02 at the end of the dispersion compensation fiber 16. That is, since the time delay is the reciprocal of a filter period, filter characteristics can be easily adjusted.

<Another embodiment>

Another embodiment proposed in the present invention is described below.

First, filters suitable for application fields can be manufactured using different mode converters. That is, a power coupling degree (efficiency) between the modes LP01 and LP02 is controlled by adjusting a diameter of a hollow optical fiber and a diameter of an empty space formed therein. Therefore, the diameter of the hollow optical fiber (including the diameter of the

empty space formed therein) is changed, so the shape of a manufactured filter (not shown) is also changed.

Second, other filter characteristics can be obtained using a plurality of laser diodes. That is, as shown in Fig. 3, if plural laser diodes 10 having different wavelengths are connected, as many LP01 modes propagating different wavelengths as the number of laser diodes 10 exist in the single mode fiber 12. Further, respective LP01 modes propagating different wavelengths are connected to the dispersion compensation fiber 16 through the first mode converter 30. The respective LP01 modes propagating different wavelengths are coupled to the LP02 mode in the dispersion compensation fiber 16. Further, the modes LP01 and LP02 in the dispersion compensation fiber 16 have group indexes corresponding to their wavelengths, so they have different group velocities. A time delay occurs due to this velocity difference, and a signal, converted into a signal of the single mode LP01 existing in the single mode fiber 12 through the second mode converter 30', is received by the receiving unit 40. As described above, other filter characteristics differing from the conventional filter characteristics can be obtained using a plurality of laser diodes having different wavelengths.

Industrial Applicability

As described above, the present invention provides a optical tunable microwave filter using a higher mode, which can construct a plurality of delay lines using a single short dispersion compensation fiber through two mode converters, differently from conventional filters, and tuning of the filter can be easily performed. Further, the present invention is advantageous in that it can obtain other filter characteristics differing from conventional filter characteristics by adjusting a diameter of a hollow optical fiber, which is a mode converter, or connecting a plurality of laser diodes having different wavelengths.

Claims

1. A optical tunable microwave filter using a higher mode, the filter having two mode converters, a single mode fiber, a dispersion compensation fiber, at least one laser diode, a modulator and a receiving unit, comprising:

the diode for generating at least one carrier signal;

the modulator for modulating the carrier signal generated by the laser diode;

the first mode converter for receiving power of the signal modulated by the modulator and dispersing the signal power, namely, the power of the signal transmitted in a single mode (LP01) in the single mode fiber, into two modes (LP01, LP02) in the dispersion compensation fiber;

the second mode converter for receiving signals of two modes (LP01 and LP02) having a time delay therebetween through the first mode converter and converting the signals of the two modes (LP01, LP02) again into a signal of a single mode (LP01) existing in the single mode fiber; and

the receiving unit for receiving the signal converted by the second mode converter.

2. The optical tunable microwave filter according to claim 1, wherein the first and second mode converters are hollow optical fibers that each couple the single mode fiber and the dispersion compensation fiber and each have a radius of 3.4μm and an empty space with a radius of 0.6μm in its center.

3. The optical tunable microwave filter according to claim 1 or 2, wherein the first mode converter is constructed so that the power is dispersed into the respective modes LP01 and LP02 in the ratio of 50: 50 in the first mode converter.

4. The optical tunable microwave filter according to claim 1 or 2,

wherein each of the first and second mode converters is constructed so that a power coupling degree (efficiency) between the modes (LP01 and LP02) is controlled by adjusting a diameter of the hollow optical fiber and a diameter of the empty space formed therein.

5. The optical tunable microwave filter according to 1, wherein the laser diode for generating the carrier signal is implemented to be plural in number, thus enabling filters having different characteristics to be manufactured.

DRAWINGS

Fig. 1

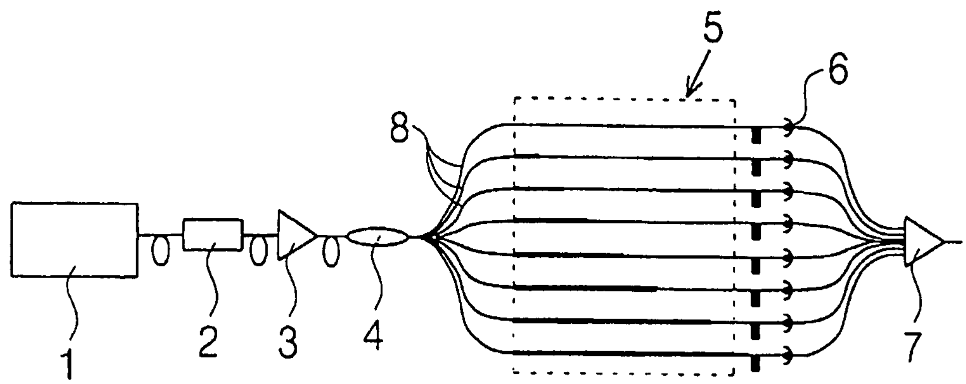


Fig. 2

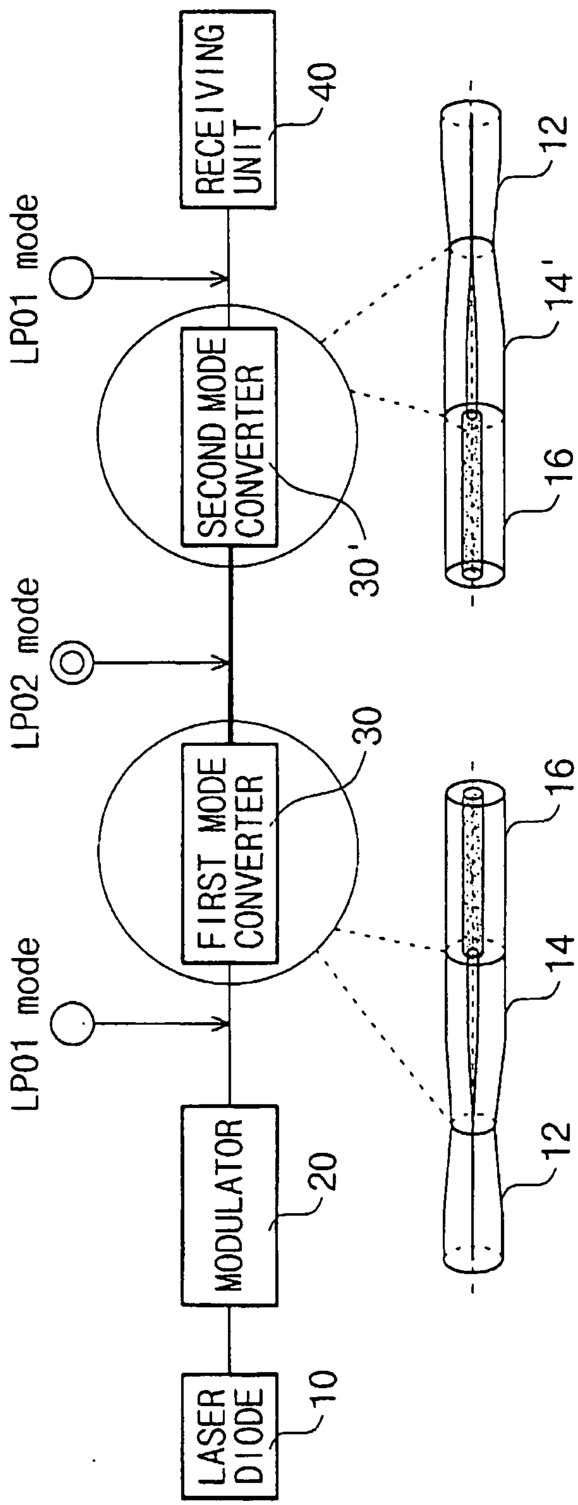
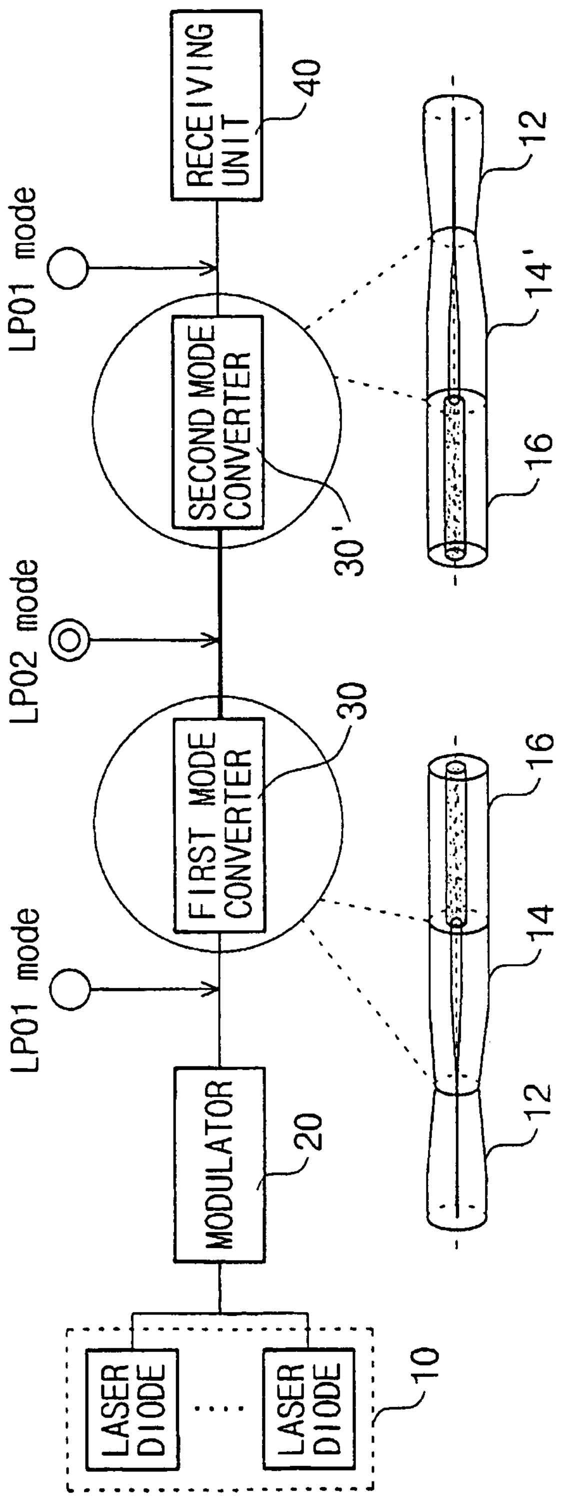

LASER DIODE
10
MODULATOR
20
LP01 mode
FIRST MODE CONVERTER
30
LP02 mode
SECOND MODE CONVERTER
30'
LP01 mode
RECEIVING UNIT
40
12
14
16
16
14'
12

Fig. 3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FIRST MODE CONVERTER
30
LP02 mode
SECOND MODE CONVERTER
30'
LP01 mode
RECEIVING UNIT
40
12
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16
14'
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INTERNATIONAL SEARCH REPORT

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PCT/KR03/00518

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G02B 5/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
KR, JP : IPC as above

Electronic data base consulted during the interntnational search (name of data base and, where practicable, search terms used)
NPS, PAJ "filter & mode converter&delay line"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5724169 A (BOEING CO.) 03 MARCH 1998 see the whole document	1
A	KR 2000-0033240 A (LEE, GYE CHEOL) 15 JUNE 2000 see the whole document	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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